Digital Elevation Model for Corpus Christi, Texas: Procedures, Data Sources and Analysis

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1. INTRODUCTION

The National Geophysical Data Center (NGDC), an office of the National Oceanic and Atmospheric Administration (NOAA), has developed a bathymetric–topographic digital elevation model (DEM) of Corpus Christi, Texas (Fig. 1) for the Pacific Marine Environmental Laboratory (PMEL) NOAA Center for Tsunami Research (http://nctr.pmel.noaa.gov/). The 1/3 arc-second[1] coastal DEM will be used as input for the Method of Splitting Tsunami (MOST) model developed by PMEL to simulate tsunami generation, propagation and inundation. The DEM was generated from diverse digital datasets in the region (grid boundary and sources shown in Fig. 3) and will be used for tsunami inundation modeling, as part of the tsunami forecast system SIFT (Short-term Inundation Forecasting for Tsunamis) currently being developed by PMEL for the NOAA Tsunami Warning Centers. This report provides a summary of the data sources and methodology used in developing the Corpus Christi DEM.
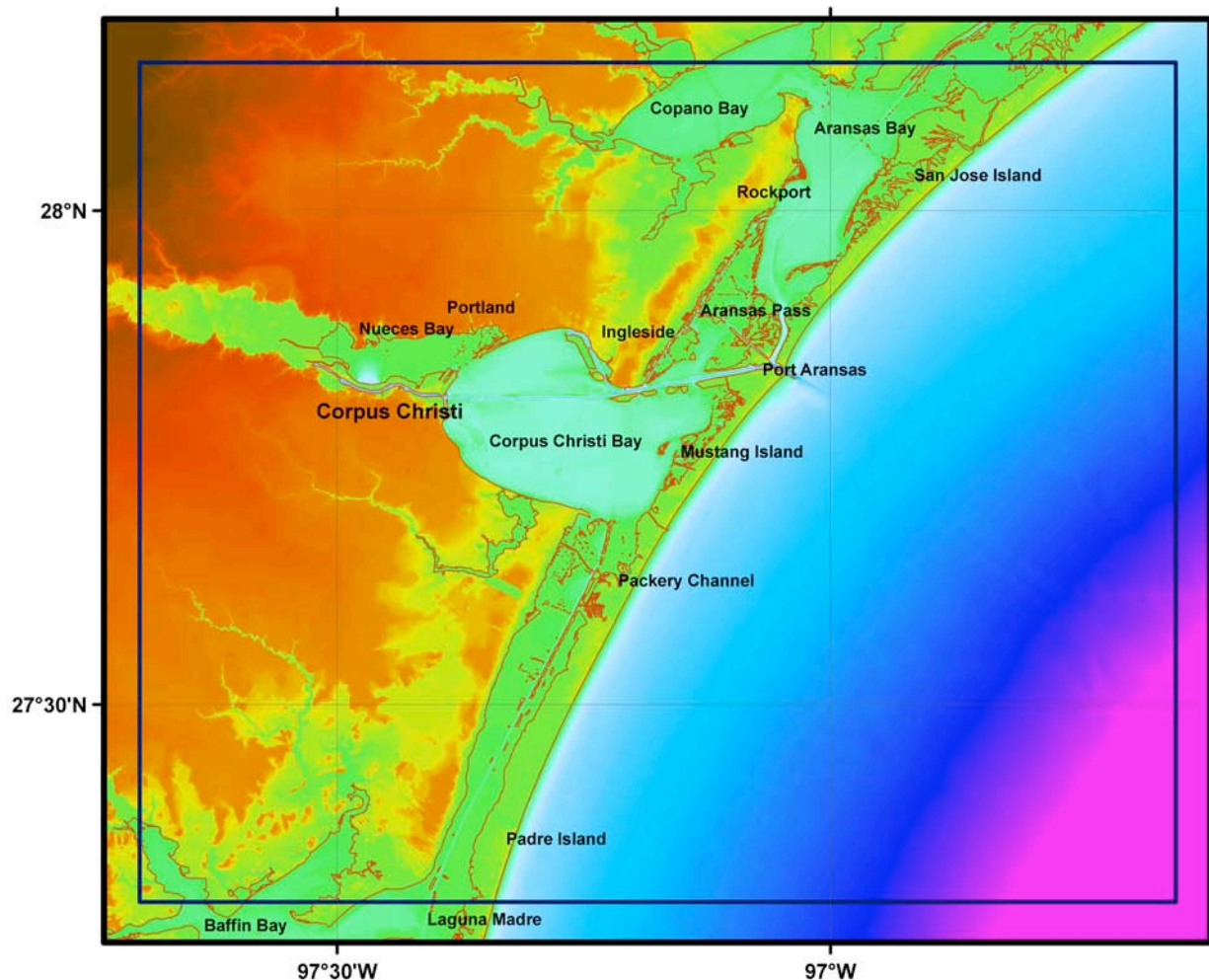
Figure 1. Color image of the Corpus Christi, Texas region. Coastline in red.

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1. The Corpus Christi DEM is built upon a grid of cells that are square in geographic coordinates (latitude and longitude); however, the cells are not square when converted to projected coordinate systems, such as UTM zones (in meters). At the latitude of Corpus Christi, Texas (27°47′ N, 97°25′ W) 1/3 arc-second of latitude is equivalent to 10.26 meters; 1/3 arc-second of longitude equals 8.92 meters.

2. STUDY AREA

The Corpus Christi DEM covers the coastal region of the Gulf coast of Texas known as the Coastal Bend, centered on the city of Corpus Christi. The DEM includes the communities of Corpus Christi, Port Aransas, Aransas Pass, Ingleside, Portland, and Rockport. It also covers Corpus Christi Bay, Aransas Bay, Nueces Bay, Copano Bay and the northern portion of Baffin Bay as well as Padre, Mustang, and San Jose Islands (Fig. 1).

The southern area of the DEM includes the northern tip of the Padre Island National Seashore separated from the mainland by Laguna Madre. Encompassing 130,434 acres and offering a wide variety of flora and fauna as well as recreation, it is the longest remaining undeveloped stretch of barrier island in the world (http://www.nps.gov/pais/planyourvisit/maps.htm).
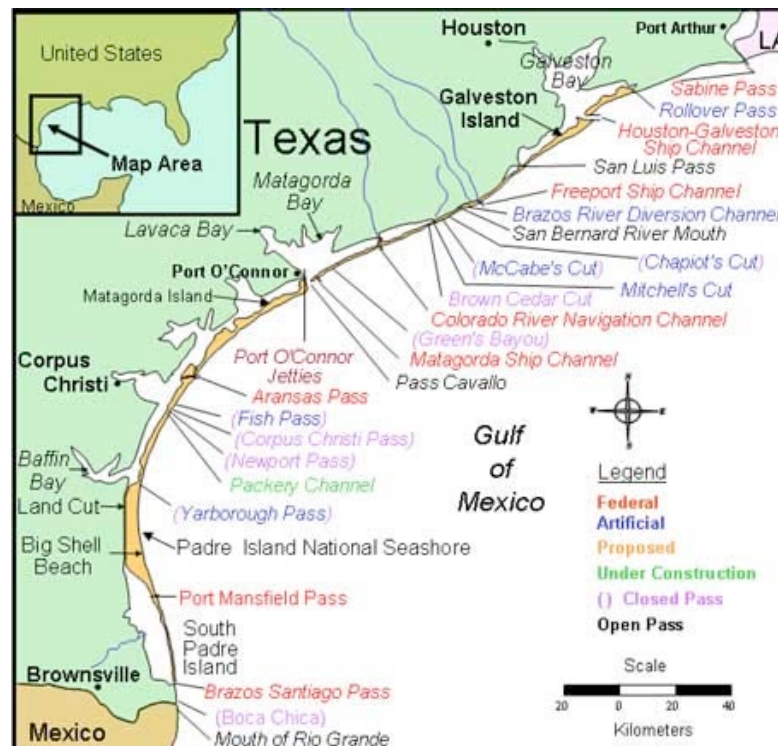
Figure 2. *Map of Texas Gulf Coast inlets*
(http://goliath.cbi.tamucc.edu/TexasInletsOnline/TIO%20Main/index.htm)

3.   METHODOLOGY

The Corpus Christi DEM was developed to meet PMEL specifications (Table 1), based on input requirements for the MOST inundation model. The best available digital data were obtained by NGDC and shifted to common horizontal and vertical datums: World Geodetic System 1984 (WGS84) and Mean High Water (MHW), for modeling of "worst-case scenario" flooding, respectively. Data processing and evaluation, and DEM assembly and assessment are described in the following subsections.

Table 1: PMEL specifications for the Corpus Christi, Texas DEM.

Grid Area	Corpus Christi, Texas
Coverage Area	96.65º to 97.7º W; 27.3º to 28.15º N
Coordinate System	Geographic decimal degrees
Horizontal Datum	World Geodetic System 1984 (WGS84)
Vertical Datum	Mean High Water (MHW)
Vertical Units	Meters
Grid Spacing	1/3 arc-second
Grid Format	ESRI ASCII raster grid

3.1   Data Sources and Processing

Shoreline, bathymetric, and topographic digital datasets (Fig. 3) were obtained from several U.S. federal, agencies, including: NOAA's National Ocean Service (NOS); the National Geospatial-Intelligence Agency; and the U.S. Geological Survey (USGS). Safe Software's (http://www.safe.com/) FME data translation tool package was used to shift datasets to WGS84 horizontal datum and to convert into ESRI (http://www.esri.com/) ArcGIS shape files. The shape files were then displayed with ArcGIS to assess data quality and manually edit datasets; NGDC's GEODAS software (http://www.ngdc.noaa.gov/mgg/geodas/) was used to manually edit large xyz datasets. Vertical datum transformations to MHW were accomplished using FME, based upon data from NOAA tide stations at Corpus Christi and offset grids (digital surfaces with values representing interpolated differences between various tidal datums and MHW) provided by PMEL.

Figure 3. *Source and coverage of datasets used to compile the Corpus Christi DEM.*

3.1.1 Shoreline

Two digital coastline datasets of the Corpus Christi region were analyzed for inclusion in the Corpus Christi DEM: NOAA Office of Coast Survey Electronic Navigational Charts and the National Geospatial-Intelligence Agency High Water Line (Table 2).

Table 2: Shoreline datasets used in compiling the Corpus Christi DEM.

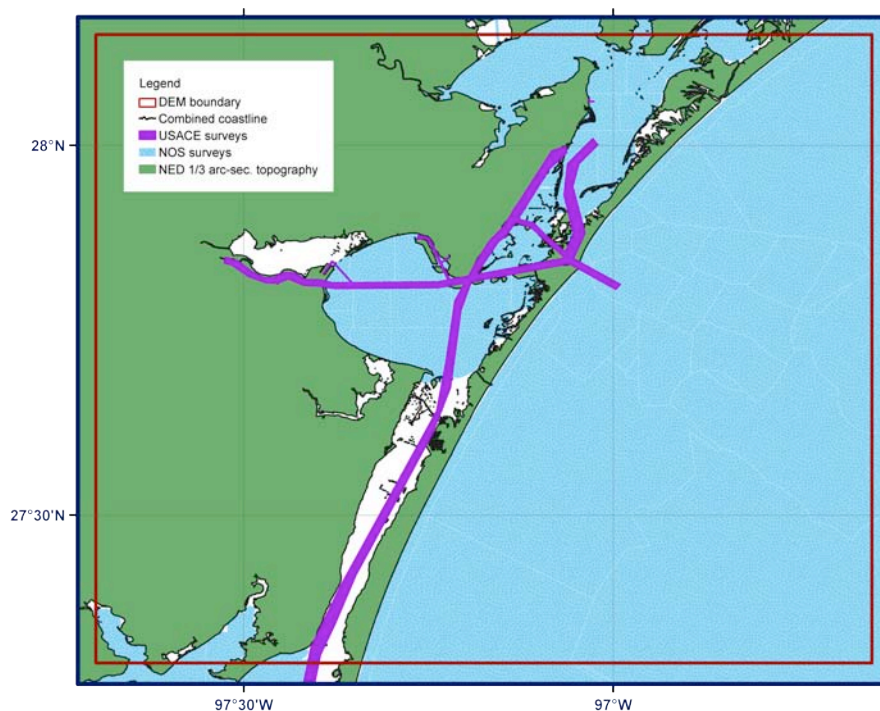| Source	Year	Data Type	Spatial Resolution	Original Horizontal Datum/Coordinate System	Original Vertical Datum	URL
NGA	2000	satellite derived High Water Line	1:75,000 or smaller	WGS84	~High Water Line	See footnote 2
OCS ENCs	1997 to 2006	Mean High Water	1:10,000 to 1:80,000	WGS84	Mean High Water	http://chartmaker.ncd.noaa.gov/

1) NOAA Office of Coast Survey Electronic Navigational Charts

Six NOAA nautical charts were available in electronic chart format (#11307, #11308, #11309, #11311, #11312 and #11313) for the Corpus Christi region (Table 3) and were downloaded from NOAA's Office of Coast Survey (OCS) website (http://chartmaker.ncd.noaa.gov/). All of the nautical charts were available in raster nautical chart (RNC) format—georeferenced map imagery, which are frequently updated—and as Electronic Navigational Charts (ENCs)—digital GIS chart components (Fig. 4). The ENCs include coastline data files (MHW), which were compared with the NGA coastline dataset, USGS topographic data, and NOS hydrographic soundings. The ENCs also include soundings (extracted from NOS hydrographic surveys) and land elevations.

The NGA coastline dataset and the six ENCs were used to build a 'combined coastline' (Fig. 4). The NOAA Coastal Services Center's 'Electronic Navigational Chart Data Handler for ArcView' extension (http://www.csc.noaa.gov/products/enc/) was used to import the ENCs into ArcGIS. Editing all of the ENC coastline data was necessary to provide more detail in areas where recent bathymetric survey data existed. RNCs were reviewed in evaluating the combined coastline to make sure that small scale features were represented correctly.

Table 3: NOAA Electronic Navigational Charts used to build the 'combined coastline' for the Corpus Christi DEM.

Chart Number	Title	Edition	Date	Scale
11307	Aransas Pass to Baffin Bay	4	06/2006	1:80,000
11308	Redfish Bay to Middle Ground Side A	2	06/2006	1:40,000
11309	Corpus Christi Bay	9	01/2007	1:40,000
11311	Corpus Christi Harbor	8	02/2007	1:10,000
11312	Corpus Christi Bay Port Aransas to Port Ingleside	8	02/2007	1:10,000
11313	Matagorda Light to Aransas Pass	3	01/2001	1:80,000
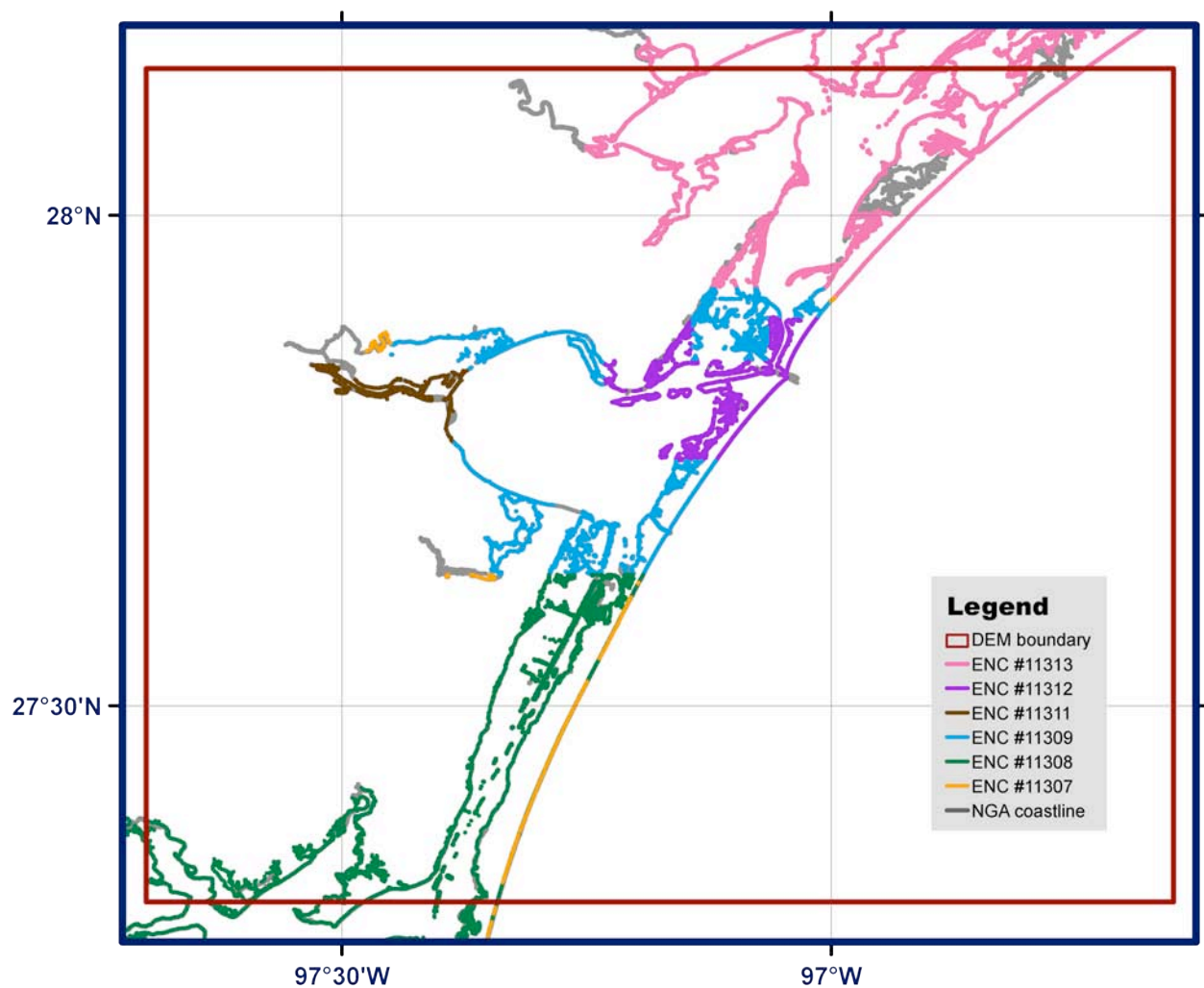
Figure 4. *NOAA Electronic Navigational Charts and NGA coastline data used to build the 'combined coastline' in the Corpus Christi region.*

2)   National Geospatial-Intelligence Agency High Water Line

The NGA Office of Global Navigation, Maritime Division[2] developed the Global Shoreline Data set from digitized orthorectified NASA, 2000 era, LANDSAT GeoCover (multi-spectral imagery). This new shoreline is an approximation of the High Water Line with a resolution of 1:75,000 or smaller. The NGA coastline provided data where the ENCs were not available.

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2 The NGA Office of Global Navigation, Maritime Division is in the process of developing a new version of World Vector Shoreline (WVS®) and in support of this effort has acquired a prototype Global Shoreline Data set. This new shoreline is an approximation of the High Water Line; it is NOT a Mean High Water Line since the source data have not been tide coordinated (http://www.nga.mil/portal/site/nga01/index.jsp?epi-content=GENERIC&itemID=9328fbd8dcc4a010VgnVCMServer3c02010aRCRD&beanID=1629630080&viewID=Article). The prototype Global Shoreline Data set (satellite derived High Water Line) in work at NGA has been acquired from orthorectified NASA, 2000 era, LANDSAT GeoCover (multi-spectral imagery). [Extracted from metadata.]

3.1.2   Bathymetry

Bathymetric datasets used in the compilation of the Corpus Christi DEM include 57 NOS hydrographic surveys and 51 USACE surveys of dredged shipping channels (Table 4).
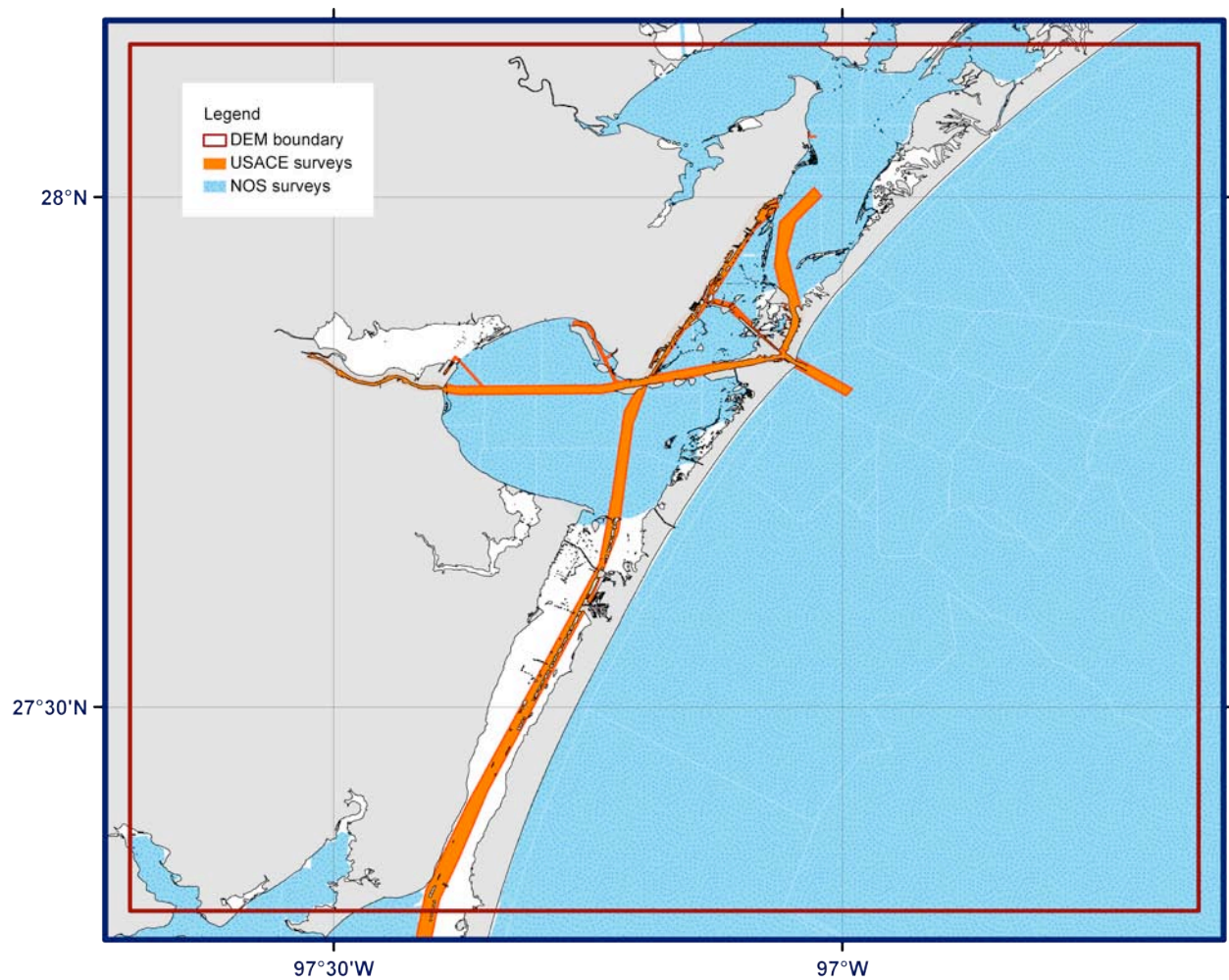
Figure 5. *Bathymetric datasets used in compiling the Corpus Christi DEM.*

Table 4: Bathymetric datasets used in compiling the Corpus Christi DEM.

Source	Year	Data Type	Spatial Resolution	Original Horizontal Datum/Coordinate System	Original Vertical Datum	URL
USACE, Galveston District	2004 to 2007	Hydrographic survey soundings	Profiles spaced 25 to 200 m apart. Point spacing along profiles <1 m.	NAD27 State Plane Texas South or South Central	Mean Low Tide	http://www.swg.usace.army.mil/ and http://beams.swg.usace.army.mil/
NOS	1934 to 1994	Hydrographic survey soundings	Ranges from 10 m to 1 km (varies with scale of survey, depth, traffic, and probability of obstructions)	NAD27 or NAD83	MLLW or MLW	http://www.ngdc.noaa.gov/mgg/bathymetry/hydro.html

1)   NOS hydrographic survey data

A total of 57 NOS hydrographic surveys conducted between 1934 and 1994 were utilized in developing the Corpus Christi DEM (Table 5; Fig. 6). The hydrographic survey data were originally vertically referenced to Mean Lower Low Water (MLLW) or Mean Low Water (MLW) and horizontally referenced to either NAD27 or NAD83 datums.

Data point spacing for the NOS surveys varied by collection date. In general, earlier surveys had greater point spacing than more recent surveys. All surveys were extracted from NGDC's online NOS hydrographic database (http://www.ngdc.noaa.gov/mgg/bathymetry/hydro.html) in their original, digitized datums (Table 5). The data were then converted to WGS84 and MHW using FME software, an integrated collection of spatial extract, transform, and load tools for data transformation (http://www.safe.com). The surveys were subsequently clipped to a polygon 0.05 degrees (~5%) larger than the Corpus Christi DEM area to support data interpolation along grid edges.

After converting all NOS survey data to MHW (see Section 3.2.1), the data were displayed in ESRI ArcMap and reviewed for digitizing errors against scanned original survey smooth sheets and compared to the NED topographic data, the combined coastline, RNCs, and *Google Earth* satellite imagery.

Table 5: Digital NOS hydrographic surveys used in compiling the Corpus Christi DEM.

NOS Survey ID	Year of Survey	Survey Scale	Original Vertical Datum	Original Horizontal Datum
H05612	1934	10,000	mean low water	NAD27
H05613	1934	10,000	mean low water	NAD27
H05693	1935	20,000	mean low water	NAD27
H05694	1935	20,000	mean low water	NAD27
H05875	1935	20,000	mean low water	NAD27
H05916	1935	20,000	mean low water	NAD27
H05917	1935	20,000	mean low water	NAD27
H06393	1938	20,000	mean low water	NAD27
H06394	1938	20,000	mean low water	NAD27
H06395	1938	20,000	mean low water	NAD27
H06396	1938	20,000	mean low water	NAD27
H06397	1938	20,000	mean low water	NAD27
H06401	1938	40,000	mean low water	NAD27
H06402	1938	40,000	mean low water	NAD27
H06403	1938	40,000	mean low water	NAD27
H06405	1938	80,000	mean low water	NAD27
H06498	1939	80,000	mean low water	NAD27
H09002	1968	20,000	mean low water	NAD27
H09005	1968	20,000	mean low water	NAD27
H10205	1985	20,000	mean lower low water	NAD27
D00107	1989	40,000	mean lower low water	NAD27
H10320	1989/90	10,000	mean lower low water	NAD83
H10321	1989/90	10,000	mean lower low water	NAD83
H10322	1989/90	10,000	mean lower low water	NAD83
H10323	1989/90	10,000	mean lower low water	NAD83
H10324	1989/90	10,000	mean lower low water	NAD83
H10325	1989/90	10,000	mean lower low water	NAD83
H10332	1989/90	10,000	mean lower low water	NAD83
H10326	1990	10,000	mean lower low water	NAD83
H10327	1990	10,000	mean lower low water	NAD83
H10328	1990	10,000	mean lower low water	NAD83
H10329	1990	10,000	mean lower low water	NAD83

H10330	1990	10,000	mean lower low water	NAD83
H10359	1990/91	10,000	mean lower low water	NAD83
H10360	1990/91	10,000	mean lower low water	NAD83
H10361	1990/91	10,000	mean lower low water	NAD83
H10362	1990/91	10,000	mean lower low water	NAD83
H10363	1990/91	10,000	mean lower low water	NAD83
H10364	1990/91	5,000	mean lower low water	NAD83
H10365	1991	10,000	mean lower low water	NAD83
H10366	1991	10,000	mean lower low water	NAD83
H10367	1991	10,000	mean lower low water	NAD83
H10368	1991	10,000	mean lower low water	NAD83
H10369	1991	10,000	mean lower low water	NAD83
H10392	1991	10,000	mean lower low water	NAD83
H10399	1991	10,000	mean lower low water	NAD83
H10402	1991	10,000	mean lower low water	NAD83
H10400	1991/92	10,000	mean lower low water	NAD83
H10401	1991/92	10,000	mean lower low water	NAD83
F00381	1992	10,000	mean lower low water	NAD83
F00386	1993	10,000	mean lower low water	NAD83
H10508	1993	10,000	mean lower low water	NAD83
H10509	1993/94	10,000	mean lower low water	NAD83
H10510	1993/94	10,000	mean lower low water	NAD83
F00402	1994	10,000	mean lower low water	NAD83
F00405	1994	10,000	mean lower low water	NAD83
H10562	1994	10,000	mean lower low water	NAD83
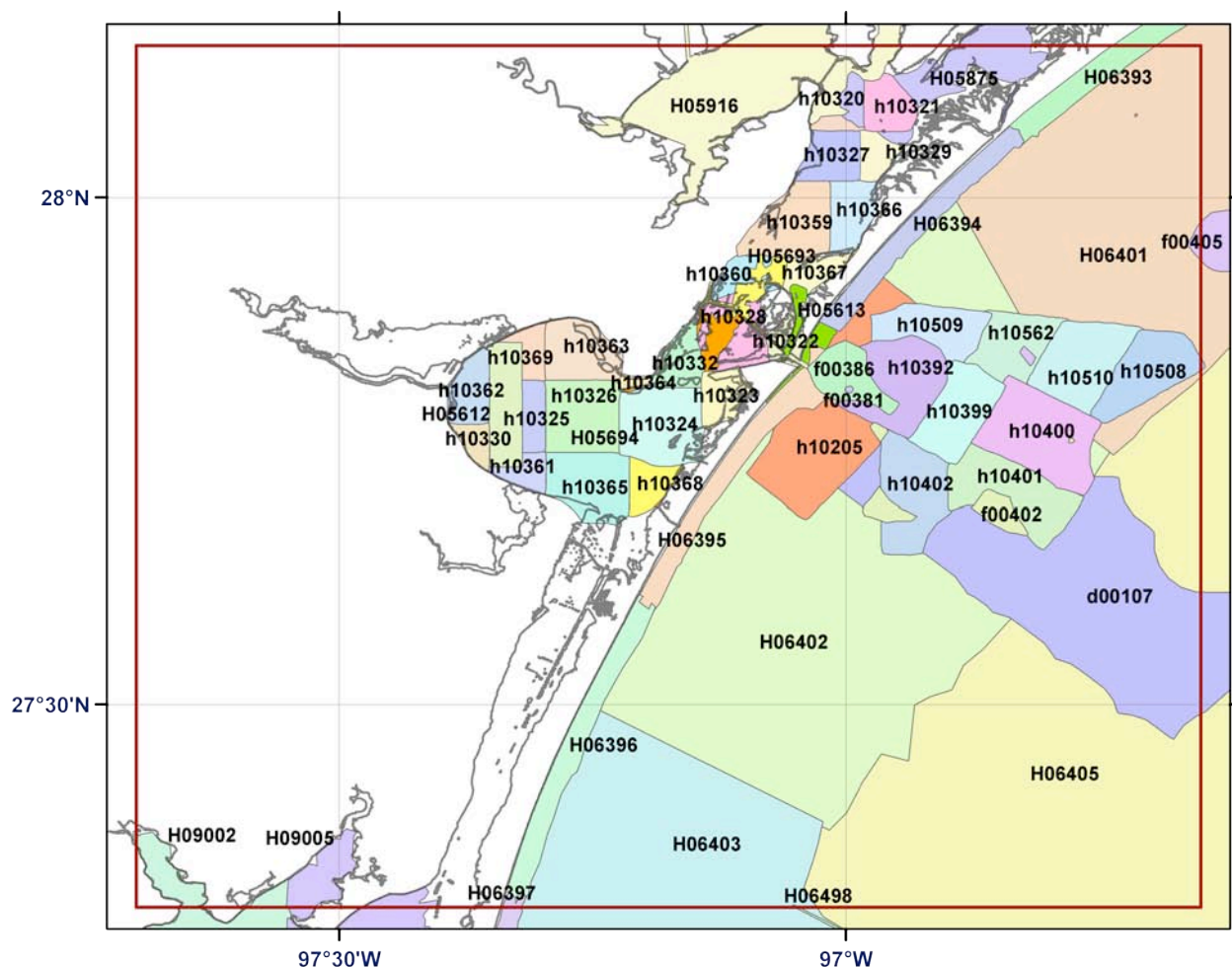
Figure 6. Digital NOS hydrographic survey coverage in the Corpus Christi region. DEM boundary in red, combined coastline in gray.

2) U.S. Army Corps of Engineers Survey

The USACE, Galveston District provided NGDC with hydrographic surveys spanning the Texas Gulf Coast within dredged shipping channels and the Intracoastal Waterway (Table 6, Fig. 7). Records in the individual survey files that contained zero latitude and longitude values were deleted and the resulting data were transformed to shapefiles using FME. The original vertical datum of Mean Low Tide (MLT) was determined to be equivalent to Mean Low Water. The surveys were reviewed and edited individually in ArcMap. Two surveys contained overlapping elevation points with conflicting values and two surveys contained incorrect single elevation points. These surveys were corrected using ArcMap editor, referencing corresponding nautical chart data.

Table 6: USACE hydrographic surveys used in compiling the Corpus Christi DEM.

Region	Original horizontal datum	Original vertical datum	Spatial Resolution
Port Aransas	NAD27 State Plane Texas South	Mean Low Tide	Profiles ~125 m long, spaced 25 to 75 m apart, with <1 m point spacing
Rincon Canal	NAD27 State Plane Texas South	Mean Low Tide	Profiles ~75 to 125 m long, spaced ~100 m apart, with <1 m point spacing
Jewl Fulton Channel	NAD27 State Plane Texas South	Mean Low Tide	Profiles ~75 to 100 m long, spaced 60 to 125 m apart, with <1 m point spacing
La Quinta Channel	NAD27 State Plane Texas South	Mean Low Tide	Profiles ~200 to 400 m long, spaced ~100 m apart, with <1 m point spacing
Fulton	NAD27 State Plane Texas South Central	Mean Low Tide	Profiles ~60 m long, spaced ~60 m apart, with <1 m point spacing
Aransas Pass	NAD27 State Plane Texas South	Mean Low Tide	Profiles ~75 m long, spaced 50 to 200 m apart, with <1 m point spacing
GIWW Corpus Christi	NAD27 State Plane Texas South Central	Mean Low Tide	Profiles ~100 m long, spaced ~75 to 100 m apart, with <1 m point spacing
Corpus Christi Shipping Channel	NAD27 State Plane Texas South	Mean Low Tide	Profiles ~250 to 500 m long, spaced ~ 30 to 130 m apart, with <1 m point spacing
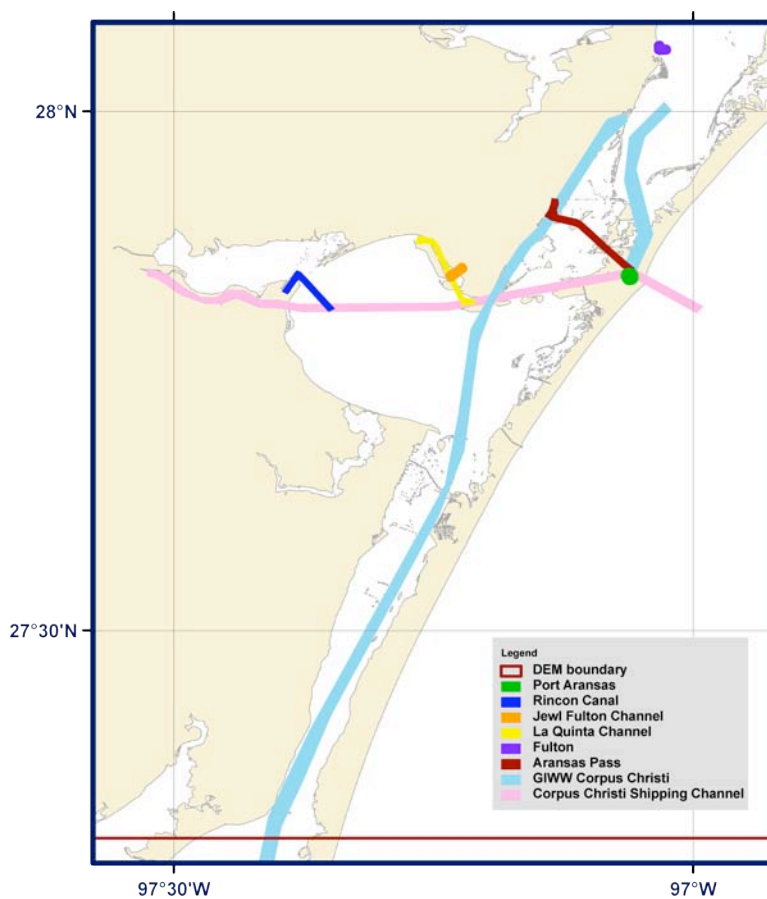
Figure 7. USACE channel surveys within the Corpus Christi DEM boundary.

3.1.3 Topography

The topographic dataset used in the Corpus Christi region was obtained from the U.S. Geological Survey (Table 7; Fig. 8).

Table 7: Topographic dataset used in compiling the Corpus Christi DEM.

Source	Year	Data Type	Spatial Resolution	Original Horizontal Datum/Coordinate System	Original Vertical Datum	URL
USGS	2001	NED 1/3 arc-second	~10 m	NAD83	NAVD88 (meters)	http://ned.usgs.gov/

1) USGS NED topography

The U.S. Geological Survey (USGS) National Elevation Dataset (NED; http://ned.usgs.gov/) provided complete 1/3 arc-second coverage of the Corpus Christi region[3]. Data are in NAD83 geographic coordinates and NGVD88 vertical datum (meters), and are available for download as raster DEMs. The extracted bare-earth elevations have a vertical accuracy of +/- 7 to 15 meters depending on source data resolution. See the USGS Seamless web site for specific source information (http://seamless.usgs.gov/). The dataset was derived from USGS quadrangle maps and aerial photographs based on topographic surveys; it has been revised using data collected in 1999 and 2004.

The NED data included "zero" elevation values over the open ocean, which were removed from the dataset before gridding. Some anomalous values still remained over the open ocean, which were visually inspected and compared with NOAA nautical charts, the combined coastline, and *Google Earth* satellite imagery. ESRI Arc Catalog was used to clip the data to the combined coastline.
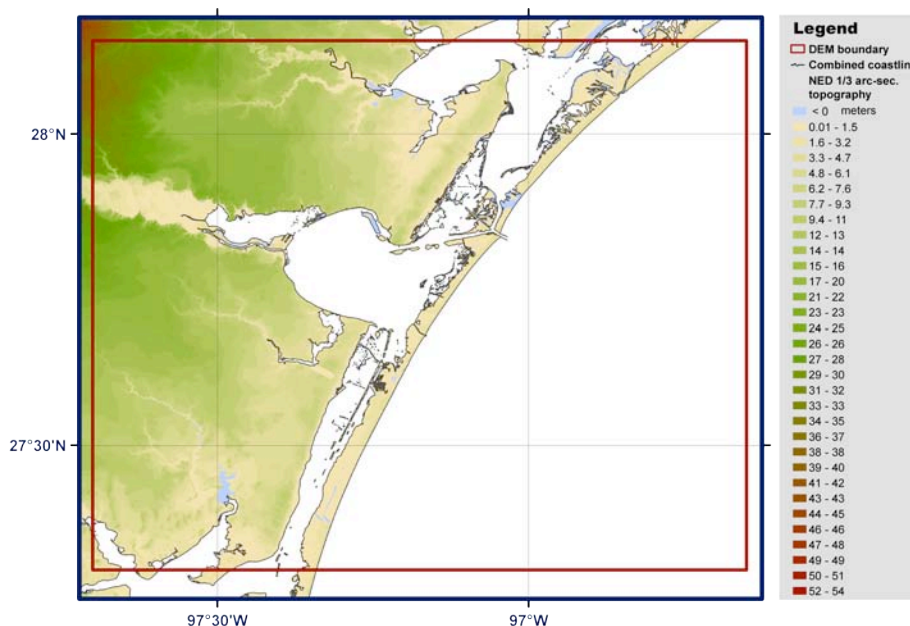

Figure 8. *USGS National Elevation Dataset (NED) data used in the Corpus Christi DEM*

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3. The USGS National Elevation Dataset (NED) has been developed by merging the highest-resolution, best quality elevation data available across the United States into a seamless raster format. NED is the result of the maturation of the USGS effort to provide 1:24,000-scale Digital Elevation Model (DEM) data for the conterminous U.S. and 1:63,360-scale DEM data for Georgia. The dataset provides seamless coverage of the United States, HI, AK, and the island territories. NED has a consistent projection (Geographic), resolution (1 arc second), and elevation units (meters). The horizontal datum is NAD83, except for AK, which is NAD27. The vertical datum is NAVD88, except for AK, which is NGVD29. NED is a living dataset that is updated bimonthly to incorporate the "best available" DEM data. As more 1/3 arc second (10 m) data covers the U.S., then this will also be a seamless dataset. [Extracted from USGS NED website]

3.2   Establishing Common Datums

3.2.1   Vertical datum transformations

Datasets used in the compilation and evaluation of the Corpus Christi DEM were originally referenced to a number of vertical datums including Mean Lower Low Water (MLLW), Mean Low Water (MLW), and North American Vertical Datum of 1988 (NAVD88). All datasets were transformed to MHW to provide the worst-case scenario for inundation modeling.

1) **Bathymetric data**

NOS and USACE hydrographic surveys were transformed from MLLW, MLW, and MLT to MHW, using FME software, by adding an offset grid provided by PMEL (Table 8).

2) **Topographic data**

The USGS NED 1/3 arc-second DEM was originally referenced to NAVD88. It was converted to MHW, using FME software by adding a tide-station derived constant offset of -0.317 (Table 8).

Table 8. Relationship between Mean High Water and other vertical datums in the Corpus Christi region.

Vertical datum	Difference to MHW
NAVD88*	-0.317
MLW	Determined by adding PMEL offset grid
Mean Low Tide[+]	Determined by adding PMEL offset grid
MLLW	Determined by adding PMEL offset grid

* Datum relationships determined by averaging values from tide stations #8775870, Corpus Christi and #8775792, Packery Channel.
+ Assumed to be equivalent to MLW.

3.2.2   Horizontal datum transformations

Datasets used to compile the Corpus Christi DEM were originally referenced to the horizontal datums of State Plane Texas South, State Plane Texas South Central, NAD27, NAD83 geographic, and WGS84 geographic. The relationships and transformational equations between these horizontal datums are well established. All data were converted to a horizontal datum of WGS84 using FME software.

3.3 Digital Elevation Model Development

3.3.1 Verifying consistency between datasets

After horizontal and vertical transformations were applied, the resulting ESRI shape files were checked in ESRI ArcMap for inter-dataset consistency. Problems and errors were identified and resolved before proceeding with subsequent gridding steps. The evaluated and edited ESRI shape files were then converted to xyz files in preparation for gridding. Problems included:

- Presence of man-made structures and river banks in coastline datasets, which had to be removed.
- Inconsistencies between the coastline datasets and bathymetric and topographic dataset. These inconsistencies are partly the result of differing resolution between datasets and of morphologic change in the highly dynamic coastal zone.
- Data values over the open ocean and rivers in the NED DEM required automated clipping to the combined coastline.
- Digital, measured bathymetric values from NOS surveys date back over 70 years. More recent data, such as USACE surveys in dredged shipping channels, differed from older, pre-dredging NOS data by as much as 10 meters. The older NOS survey data were excised where more recent bathymetric data exists.

3.3.2 Interpolating between USACE hydrographic profiles

USACE hydrographic surveys were conducted along profiles perpendicular to the axis of each channel. Data points along the profiles are very closely spaced (up to 1 m apart), but the distance between the profiles can be as great as several hundreds of meters. Spatially interpolating in areas that contain dredged channels produced a poor representation of the channels due to large distances between profiles. To remedy this, we developed custom code that takes three points in each profile (middle, first and the last), identifies similar points in the next profile, and performs a linear interpolation between the two sets of points. The resulting dataset contains three lines of closely spaced points (10 m apart or less) located in the middle and along the borders of the channel, thus providing a more realistic representation of the channel.

3.3.3 Smoothing of bathymetric data

The NOS hydrographic surveys are generally sparse at the resolution of the 1/3 arc-second Corpus Christi DEM: in deep water, the NOS survey data have point spacings up to 2 km apart. In order to reduce the effect of artifacts in the form of lines of "pimples" in the DEM due to this low resolution dataset, and to provide effective interpolation into the coastal zone, a 1 arc-second-spacing 'pre-surface' or grid was generated using GMT, an NSF-funded share-ware software application designed to manipulate data for mapping purposes (http://gmt.soest.Texas.edu/).

The NOS hydrographic point data, in xyz format, were combined with the USACE soundings into a single file, along with points extracted from the combined coastline—to provide a "zero" buffer along the entire coastline. These point data were then median-averaged using the GMT tool 'blockmedian' to create a 1 arc-second grid 0.05 degrees (~5%) larger than the Corpus Christi DEM gridding region. The GMT tool 'surface' then applied a tight spline tension to interpolate cells without data values. The GMT grid created by 'surface' was converted into an ESRI Arc ASCII grid file, and clipped to the combined coastline (to eliminate data interpolation into land areas). The resulting surface was compared with the original soundings to ensure grid accuracy (e.g., Fig. 9), converted to a shape file, and then exported as an xyz file for use in the final gridding process (see Table 9).
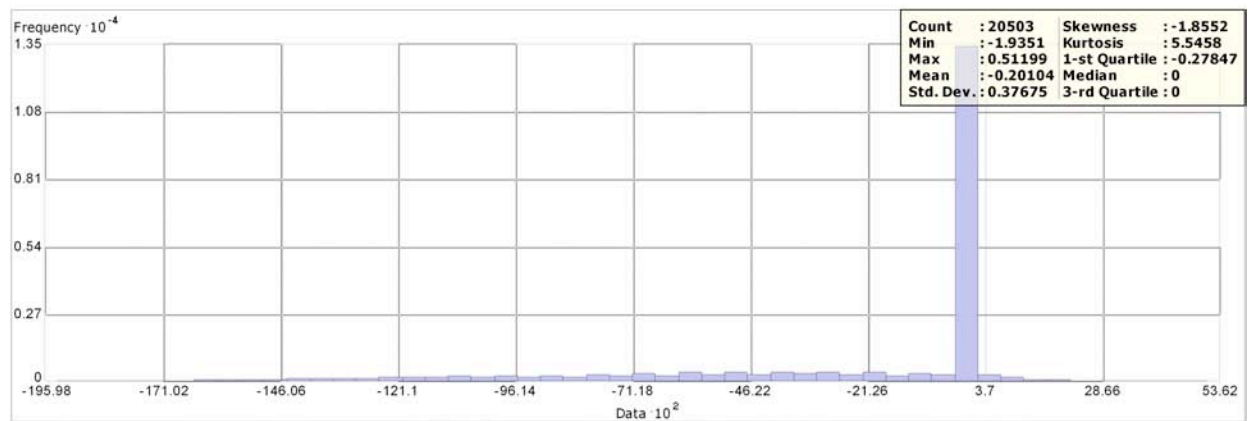
Figure 9. *Histogram of the difference between NOS hydrographic survey H10401 and the 1 arc-second pre-surfaced bathymetric grid. Discrepancies between survey soundings and the pre-surface grid result from the averaging of several closely spaced soundings.*

3.3.4   *Gridding the data with MB-System*

MB-System (http://www.ldeo.columbia.edu/res/pi/MB-System/) was used to create the 1/3 arc-second Corpus Christi DEM. MB-System is an NSF-funded share-ware software application specifically designed to manipulate submarine multibeam sonar data, though it can utilize a wide variety of data types, including generic xyz data. The MB-System tool 'mbgrid' applied a tight spline tension to the xyz data, and interpolated values for cells without data. The data hierarchy used in the 'mbgrid' gridding algorithm, as relative gridding weights, is listed in Table 9. Greatest weight was given to the USGS NED toprographic DEM. Least weight was given to the pre-surfaced 1 arc-second bathymetric grid. Gridding was performed in quadrants, each with a 5% data overlap buffer. The resulting Arc ASCII grids were seamlessly merged in ArcCatalog to create the final 1/3 arc-second Corpus Christi DEM.

Table 9. Data hierarchy used to assign gridding weight in MB-System.

Dataset	*Relative Gridding Weight*
USACE hydrographic surveys	100
USGS NED topographic DEM	1000
NOS hydrographic surveys: bathymetric soundings	100
Pre-surfaced bathymetric grid	1

3.4   Quality Assessment of the DEM

3.4.1. *Horizontal accuracy*

The horizontal accuracy of topographic and bathymetric features in the Corpus Christi DEM is dependent upon the datasets used to determine corresponding DEM cell values. Topographic features within the NED topographic dataset have an estimated accuracy of 15 meters. Bathymetric features are resolved only to within a few hundred meters in deep-water areas. Shallow, near-coastal regions, rivers, and dredged shipping channels have an accuracy approaching that of subaerial topographic features. Positional accuracy is limited by: the sparseness of deep-water soundings; potentially large positional uncertainty of pre-satellite navigated (e.g., GPS) NOS hydrographic surveys; and by the rapid morphologic change that occurs in this dynamic region.

3.4.2   *Vertical accuracy*

Vertical accuracy of elevation values for the Corpus Christi DEM is also highly dependent upon the source datasets contributing to DEM cell values. Topographic areas have an estimated vertical accuracy up to 7 meters for NED topography. Bathymetric areas have an estimated accuracy of between 0.1 meters and 5% of water depth. These values were derived from the wide range of input data sounding measurements from the early 20th century to recent, GPS-navigated sonar surveys. Gridding interpolation to determine values between sparse, poorly-located NOS soundings degrades the vertical accuracy of elevations in deep water.

3.4.3   *Slope maps and 3-D perspectives*

ESRI ArcCatalog was used to generate a slope grid from the Corpus Christi DEM to allow for visual inspection and identification of artificial slopes along boundaries between datasets (e.g., Fig. 19). The DEM was transformed to UTM Zone 15 coordinates (horizontal units in meters) in ArcCatalog for derivation of the slope grid; equivalent horizontal and vertical units are required for effective slope analysis. Three-dimensional viewing of the UTM-transformed DEM (e.g., Fig. 10) was accomplished using ESRI ArcScene. Analysis of preliminary grids revealed suspect data points, which were corrected before recompiling the DEM. Figure 1 shows a color image of the 1/3 arc-second Corpus Christi DEM in its final version.
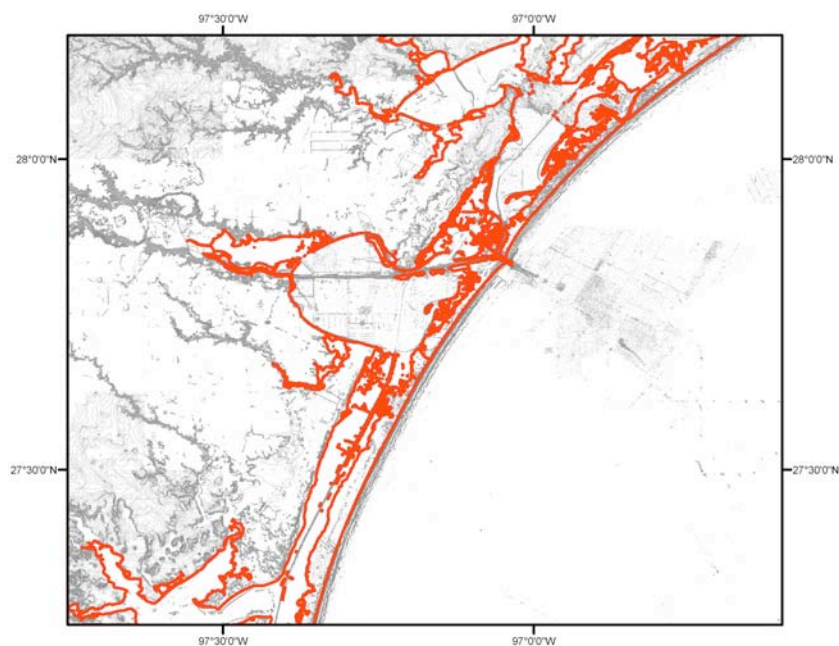

Figure 10. *Slope map of the Corpus Christi DEM. Flat-lying slopes are white; dark shading denotes steep slopes; combined coastline in red.*
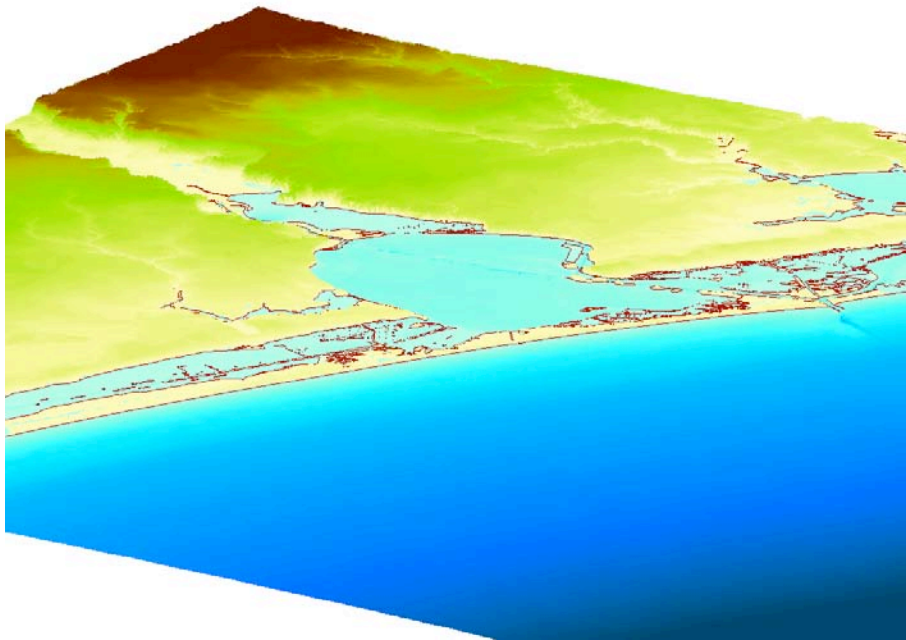
Figure 11. *Perspective view from the south of the Corpus Christi DEM. Combined coastline in red; vertical exaggeration–times 40.*

3.4.4   Comparison with source data files

To ensure grid accuracy, the Corpus Christi DEM was compared to select source data files. Files were chosen on the basis of their contribution to the grid-cell values in their coverage areas (i.e., had the greatest weight and did not significantly overlap other data files with comparable weight). A histogram of the difference between a NED topographic dataset and the Corpus Christi DEM is shown in Figure 12.
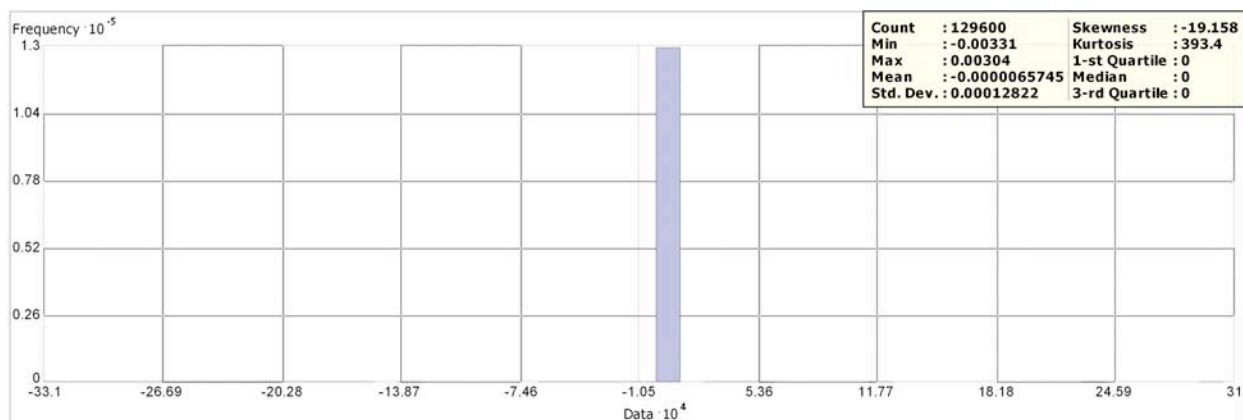

Figure 12. *Histogram of the difference between NED topographic data and the Corpus Christi DEM.*

3.4.5   Comparison with NGS geodetic monuments

The elevations of 255 NOAA NGS geodetic monuments were extracted from online shape files of monument datasheets (http://www.ngs.noaa.gov/cgi-bin/datasheet.prl), which give monument positions in NAD83 (sub-mm accuracy) and elevations in NAVD88 (in meters). Elevations were shifted to MHW vertical datum (see Table 9) for comparison with the Corpus Christi DEM (see Fig. 14 for monument locations). Differences between the Corpus Christi DEM and the NGS geodetic monument elevations range from -19 to 2.6 meters, with a negative value indicating that the monument elevation is less than the DEM (Fig. 13). Examination of the monuments with the largest positive and negative offsets from the DEM revealed that the most of them are located on the top of the man made structures such as bridges and buildings.
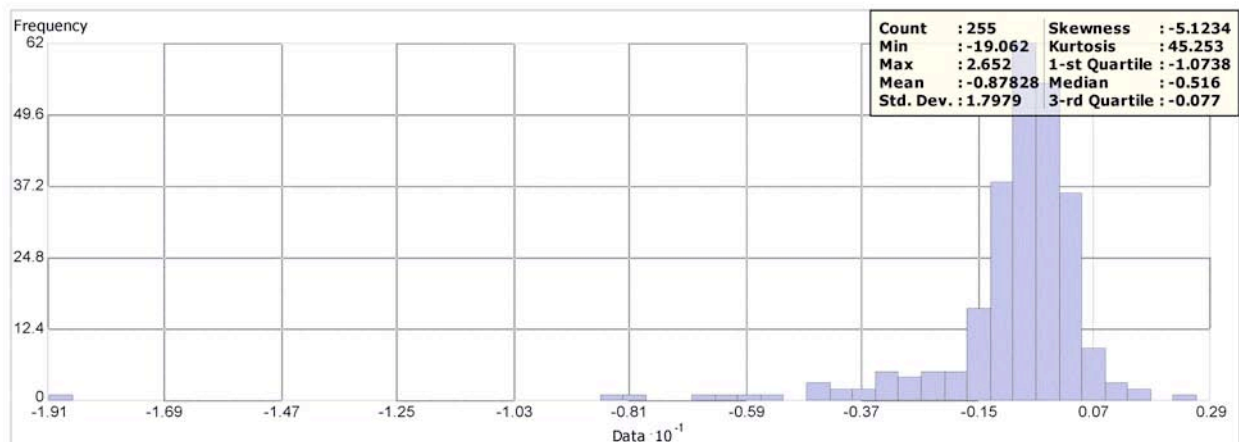

Figure 13. Histogram of the differences between NGS geodetic monument elevations and the Corpus Christi DEM.
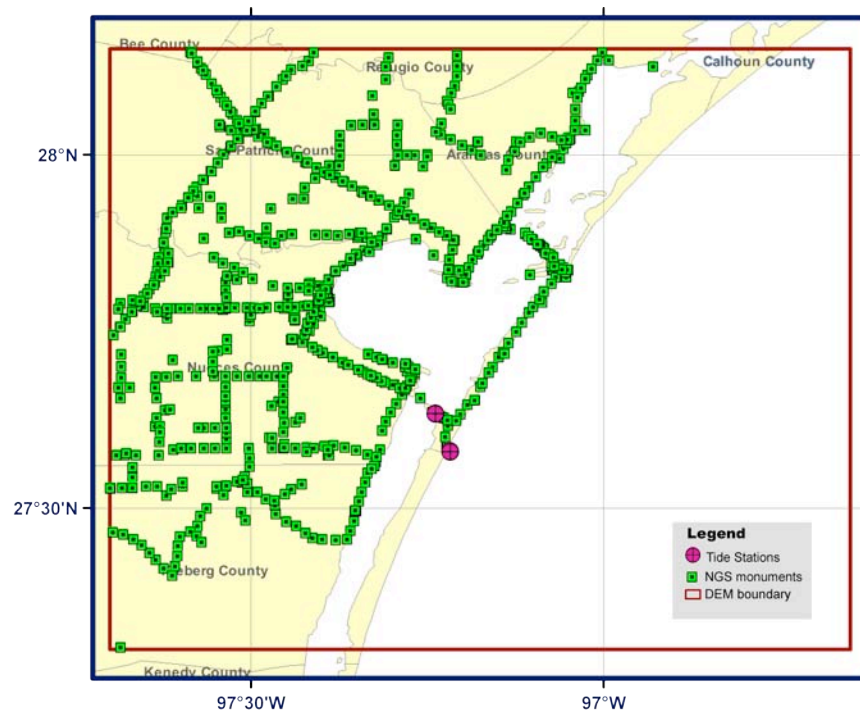
Figure 14. Location of NGS monuments and NOAA tide stations in the Corpus Christi region. Tide station used to convert between vertical datums; NGS monument elevations used to evaluate the DEM.

4. SUMMARY AND CONCLUSIONS

A topographic–bathymetric digital elevation model of the Corpus Christi, Texas region, with cell spacing of 1/3 arc-second, was developed for the Pacific Marine Environmental Laboratory (PMEL) NOAA Center for Tsunami Research. The best available digital data from U.S. federal and state agencies were obtained by NGDC, shifted to common horizontal and vertical datums, and evaluated and edited before DEM generation. The data were quality checked, processed and gridded using ESRI ArcGIS, FME, GMT, and MB-System software.

Recommendations to improve the Corpus Christi DEM, based on NGDC's research and analysis, are listed below:
- Incorporate Texas Water Development Board topographic LiDAR when available.
- Incorporate topographic LIDAR data collected by the University of Texas at Austin, Bureau of Economic Geology in 2000 from Aransas Pass to the Padre Island National Seashore when available.

5. ACKNOWLEDGMENTS

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6. REFERENCES

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Nautical Chart #11308, 23rd Edition, 2005. Redfish Bay to Middleground (Side A). Scale 1:40,000. U.S. Department of Commerce, NOAA, National Ocean Service, Coast Survey.

Nautical Chart #11309, 38th Edition, 2006. Corpus Christi Bay. Scale 1:40,000. U.S. Department of Commerce, NOAA, National Ocean Service, Coast Survey.

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Nautical Chart #11313, 23rd Edition, 2005. Matagorda Light to Aransas Pass. Scale 1:80,000. U.S. Department of Commerce, NOAA, National Ocean Service, Coast Survey.

7. DATA PROCESSING SOFTWARE

ArcGIS v. 9.2, developed and licensed by ESRI, Redlands, California, http://www.esri.com/

Electronic Navigational Chart Data Handler for ArcView, developed by NOAA Coastal Services Center, http://www.csc.noaa.gov/products/enc/

FME 2006 GB – Feature Manipulation Engine, developed and licensed by Safe Software, Vancouver, BC, Canada, http://www.safe.com/

GEODAS v. 5 – Geophysical Data System, shareware developed and maintained by Dan Metzger, NOAA National Geophysical Data Center, http://www.ngdc.noaa.gov/mgg/geodas/

GMT v. 4.1.4 – Generic Mapping Tools, shareware developed and maintained by Paul Wessel and Walter Smith, funded by the National Science Foundation, http://gmt.soest.Texas.edu/

MB-System v. 5.1.0, shareware developed and maintained by David W. Caress and Dale N. Chayes, funded by the National Science Foundation, http://www.ldeo.columbia.edu/res/pi/MB-System/